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JANET K. KERN *University of Texas Southwestern Medical Center, Dallas, USA*

MADHUKAR H. TRIVEDI *University of Texas Southwestern Medical Center, Dallas, USA*

CAROLYN R. GARVER *Autism Treatment Center, Dallas, USA*

BRUCE D. GRANNEMANN *University of Texas Southwestern Medical Center, Dallas, USA*

ALONZO A. ANDREWS *Autism Treatment Center, San Antonio, USA*

JAYSHREE S. SAVLA *University of Texas Southwestern Medical Center, Dallas, USA*

DANNY G. JOHNSON *University of Texas Southwestern Medical Center, Dallas, USA*

JYUTIKA A. MEHTA *University of Texas Southwestern Medical Center, Dallas, USA*

JENNIFER L. SCHROEDER *University of Texas Southwestern Medical Center, Dallas, USA*

ABSTRACT The study was undertaken to evaluate the nature of sensory dysfunction in persons with autism. The cross-sectional study examined auditory, visual, oral, and touch sensory processing, as measured by the Sensory Profile, in 104 persons with a diagnosis of autism, 3–56 years of age, gender- and age-matched to community controls. Persons with autism had abnormal auditory, visual, touch, and oral sensory processing that was significantly different from controls. This finding was also apparent when the high and low thresholds of these modalities were examined separately. At later ages for the group with autism, lower levels of abnormal sensory processing were found, except for low threshold touch, which did not improve significantly. There was a significant interaction in low threshold auditory and low threshold visual, suggesting that the two groups change differently over time on these variables. These results suggest that sensory abnormalities

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in autism are global in nature (involving several modalities) but have the potential to improve with age.

ADDRESS *Correspondence should be addressed to:* JANET K. KERN, *PhD, Department of Psychiatry, University of Texas Southwestern Medical Center at Dallas, 6363 Forest Park Road, Suite 13.354, Dallas, Texas, USA 75390-9119. e-mail: janet.kern@UTSouthwestern.edu*

Introduction

In addition to the core diagnostic criteria for autism (American Psychiatric Association, 1994), persons with autism exhibit associated clinical features (Filipek et al., 1999) that include problems with attention and orientation, and an odd response to the environment and sensory stimuli. Often reported is an over-sensitivity to noise, light, or touch, a high threshold for pain, and abnormal reactions to odors (American Psychiatric Association, 1994).

Although autism is a heterogeneous disorder and persons with autism present with varying clinical pictures, sensory difficulties are often described. A study conducted by Kern et al. (2001) of 39 children with a diagnosis of autism or PDD, 3 to 11 years of age, found that sensory difficulties were one of the most common of the associated clinical features seen in the children.

The words 'sensory defensiveness, disorder, dysfunction, or overload' are among those used to describe this problem in persons with autism (O'Neill and Jones, 1997). This defensiveness (defined as being sensory sensitive or having a low threshold for response to stimuli) is described in several sensory modalities and can include tactile, oral, visual, and auditory defensiveness. A brief description is as follows:

1 *Tactile defensiveness* may manifest as an avoidance of being touched, by an apparent discomfort from wearing certain clothes, or from the presence of tags on clothes (Baranek et al., 1997a; Kern et al., 2001; Wilbarger and Wilbarger, 1991). Also, there may be a resistance to hair brushing and washing (Kern et al., 2001).
2 *Oral defensiveness* may manifest as the avoidance of certain foods (involving both taste and textures), or in a willingness to eat only an extremely restricted variety of foods. Sometimes, oral defensiveness necessitates having to be fed with a syringe (Kern et al., 2001). Teeth brushing may also pose difficulties (Wilbarger and Wilbarger, 1991).
3 *Visual defensiveness* may manifest as an apparent discomfort from lights, particularly bright lights (Baranek et al., 1997b; Kern et al., 2001).
4 *Auditory defensiveness* or hyperacusis may manifest by a discomfort or painful response to noises, sometimes certain types of noises in

> particular, such as the sounds of vacuum cleaners or school bus engines (Kern et al., 2001; Rosenhall et al., 1999). This is most acute where the noise level is high or where there are many different sources of noise, such as restaurants (Kern et al., 2001). Anecdotal reports suggest that some persons with hyperacusis are able to hear sounds that others cannot hear.

Sensory processing problems are not limited to defensiveness. In contrast, some children with autism are described as being 'sensory seeking' (defined as sensory insensitive or having a high threshold for response to stimuli) (Watling et al., 2001). Sometimes a combination of defensiveness and an apparent insensitivity may be described. While persons with autism may be hypersensitive to some sounds, they may appear to be deaf to others; they may become fixated on certain stimuli, while being unaware of others (Frith, 1992). Frith (1992) also suggests that a person with autism may focus on an earring while being unaware of the person wearing it, and this may be due, in part, to sensory processing problems. The degree of sensory difficulties in different domains can affect functioning in many different activities of daily living.

Research in sensory processing suggests that children with autism process sensory information differently than typical children. Rosenhall et al. (1999), in a study that examined hearing loss in children and adolescents with autistic disorder (N = 199), found that 18 percent had hyperacusis as compared to 0 percent of controls (typical children). Baranek et al. (1997b) found that, among persons with autism and stereotypic behavior, 30 percent of the children (N = 88) and 11 percent of the adults (N = 158) showed auditory sensory disorder; 11 percent of the children and 7 percent of the adults were tactile defensive (no control group was used). Kientz and Dunn (1997) found that in children 3 to 10 years of age with autistic disorder (N = 32), sensory processing skills were different from the children without autism on 85 percent of the items of the Sensory Profile (Dunn, 1999); they also found that there were no group differences between the children with mild or moderate autism and the children with severe autism. Dahlgren and Gillberg (1989) found that 100 percent of children with autism less than 3 years of age (N = 26) had auditory processing abnormalities as compared to 0 percent controls (typical children). Later, Gillberg et al. (1990) examined children with autism less than 3 years of age (N = 12) and found that 83 percent had sensory processing abnormalities (no control group was used). Baranek et al. (1997a) found that children with autism/PDD with higher levels of tactile defensiveness (N = 28) were also more likely to show rigid, inflexible behaviors and repetitive verbalizations. Rogers et al. (2003) studied 26 toddlers with autism

comparing them to children with fragile X syndrome (n = 20), children with developmental disabilities (n = 32), and typically developing children (n = 24). The toddlers with autism and the toddlers with fragile X syndrome were not significantly different from each other, but were both significantly different overall from the other two groups, displaying more sensory symptoms, particularly in tactile sensitivity and auditory filtering. The toddlers with autism were significantly more symptomatic than the other three groups on smell and taste. Watling et al. (2001) compared 40 children with autism, 3–6 years of age, to 40 children without autism, 3–6 years of age, using the Sensory Profile. Sensory processing was significantly different on 8 out of 10 factors. These factors included: sensory seeking, emotionally reactive, oral sensitivity, poor registration, fine motor/perceptual, attention/distractibility, and low endurance/tone. Watling and colleagues stated that their findings suggest that children with autism have sensory processing deficits in a variety of areas.

The purpose of this current study was to understand better the extent of and the role of sensory dysfunction in autism. The initial hypotheses posited were: (1) persons with autism will show a higher incidence of tactile, oral, auditory, and visual dysfunction as compared to community controls; and (2) expression of sensory dysfunction will be different at different ages.

Methods

Participant selection

The study was a cross-sectional study of 104 persons with a diagnosis of autism, 3 to 56 years of age, gender- and age-matched to 104 community controls (see Table 1 for demographic information). The participants were recruited across seven age categories (3–7; 8–12; 13–17; 18–22; 23–27; 28–32; and 33+) in order to ensure a full range of ages and a balance of participants in the seven categories. Each category had no fewer than 12 participants.

The persons in the group with autism had been given a diagnosis of autism during childhood. The diagnosis was confirmed at the time of the study by one of the investigators (JKK, CRG, AAA, or JAM) based on the DSM-IV (American Psychiatric Association, 1994) criteria and clinical judgment. Each of these investigators has had at least 8 years of experience as a professional in the field. To determine the severity of the autistic symptoms, the Childhood Autism Rating Scale (CARS: Schopler et al., 1994) was completed on all subjects in the autism group (see Table 1 for CARS information). The only exclusion criteria were the presence of blindness or deafness.

Table 1 **Demographics**

Setting	*Age Mean (SD)*	*Age Range*	*CARS Mean (SD)*	*CARS Range*
ATC Dallas				
n = 40	22.68 (11.97)	5–56	43.06 (9.13)	26.5–58.5
ATC San Antonio				
n = 28	27.32 (8.57)	10–37	46.34 (7.21)	33.5–58
Autism societies				
n = 36	11.11 (7.77)	3–31	36.65 (7.03)	20.5–50.5
All settings				
n = 104	19.92 (11.42)	3–56	41.73 (8.80)	20.5–58.5
Gender				
Females				
n = 25	21.54 (10.62)	4–37	41.84 (8.91)	26.5–58.5
Males				
n = 79	19.44 (11.66)	3–56	41.70 (8.82)	20.5–58

Forty of the 104 participants with autism were residents of the Autism Treatment Center (ATC) in Dallas; 28 of the participants were from the ATC in San Antonio; and 36 were from the local autism societies (see Table 1 for demographic information). For the autism group, informed consent was signed by the parent, legal guardian, or caseworker.

The controls had no history of mental illness, learning, neurological, or developmental disorders (as reported by the parent or subject on a survey and history). No formal psychiatric assessment was conducted on the control group. Participants for the control group were identified from the Dallas Metroplex and Collin County area. For the control group, informed consent was signed by the participant (if 18 years of age or older), or by the parent (if less than 18 years of age).

Measures

The Sensory Profile (Dunn, 1999) and the Childhood Autism Rating Scale (CARS: Schopler et al., 1994) were completed for each of the 104 participants in the autism group. For the control group, only the Sensory Profile was completed.

At the ATC, the Sensory Profile was completed by a teacher, a job coach, a facilitator, a group home manager, or a therapist who was very familiar with the participant, seeing him or her 5 days per week. For the participants with autism from the local autism societies, the Sensory Profile was completed by a family member (typically a parent).

In the control group, the Sensory Profile was completed by a family member (typically a parent) if the participants were under 21 years of age.

For participants over 21 years of age, the Sensory Profile was completed by a family member (typically a spouse) whenever possible (62%); however, some of the Sensory Profiles were completed by the participant (38%).

The CARS was completed by the same person who completed the Sensory Profile with the assistance of one of the investigators: JKK (40 subjects from the ATC in Dallas and 31 participants from the general population in the Dallas Metroplex, Fort Worth, and Collin County area of community); AAA (28 participants from the ATC in San Antonio where he is the director); or JAM (five participants from her practice).

Sensory Profile The Sensory Profile is a 125-question caregiver-completed profile that reports the frequency of the person's response to various sensory experiences (Dunn, 1999). This study used four sections of the Sensory Profile: auditory processing; visual processing; touch processing; and oral sensory processing.

Autism rating The CARS (Schopler et al., 1994) is a 15-item behavioral rating scale developed to identify autism as well as quantitatively describe the severity of the disorder.

Statistical analyses

Four sections from the Sensory Profile were examined: auditory processing; visual processing; oral sensory processing; and touch processing. Prior to the analyses, all dependent measures were tested to determine if they met the assumption of normality. This was assessed because 15 to 20 percent of the scores reached the maximum score, indicating that none of the sensory items was endorsed. Since none of the four general measures or the high/low threshold subscales of these measures met this assumption, the data were transformed into seven intervals for the purpose of analyses, with the data being evenly distributed across the seven intervals, such that there were no fewer than 24 responses to any interval. For these scales, 0 indicates no response and 6 indicates the strongest response. All of the reported analyses were conducted using the transformed data scores.

To provide protection from type II error, a multivariate analysis of variance (MANOVA) was conducted with the four sensory measures as the repeated measures, with diagnostic group (autism, control) and age group (3–7, 8–12, 13–17, 18–22, 23–27, 28–32, 33+) as between-group factors. To test for specific differences within each of the sensory modalities, an individual analysis of variance (ANOVA) was conducted with each of the four sensory measures. Sensory scores for high and low thresholds were also analyzed to determine if the effects were due to general differences in sensory processing or to either hyper- or hyposensitivity. Finally, regression

analyses were conducted using age as the independent measure for each group alone.

Results

Overall

In order to control for the use of multiple outcome measures, a MANOVA was conducted using the transformed auditory, visual, touch, and oral sensory processing measures as repeated measures with diagnostic group (autism, control) and age group (3–7, 8–12, 13–17, 18–22, 23–27, 28–32, 33+) as between-group factors. There was a significant group by age effect ($F(6, 194) = 2.81$, $p < 0.02$), indicating that there were significant differences between the participants with autism and the controls and that these differences were age dependent. To test for specific differences, a 2×7 ANOVA was conducted separately for each of the auditory, visual, touch, and oral sensory processing measures.

Auditory sensory processing

The ANOVA for auditory processing showed a significant main effect for group ($F(1, 194) = 95.21$, $p < 0.0001$): autism ($\bar{X} = 4.26$, SD = 1.75), controls ($\bar{X} = 2.01$, SD = 1.65). There was a main effect for age ($F(6, 194) = 3.14$, $p < 0.006$). These main effects were qualified by a significant group by age effect ($F(6, 194) = 3.35$, $p < 0.004$) (see Table 2), indicating a difference between the autism group and the control group in changes in auditory processing with age. The regression analysis for the autism group showed a significant negative slope ($b = -0.37$, $t(102) = -5.13$, $p < 0.0001$), indicating a decrease in abnormal auditory processing over age. The regression for the controls was not significant ($t(102) < 1$), indicating no significant change.

Low threshold auditory processing showed a significant main effect for group ($F(1, 194) = 28.32$, $p < 0.0001$): autism ($\bar{X} = 2.41$, SD = 1.44), controls ($\bar{X} = 1.48$, SD = 1.18). There was a significant main effect for age ($F(6, 194) = 3.06$, $p < 0.007$) (see Table 2). These main effects are qualified by a significant group by age effect ($F(6, 194) = 6.62$, $p < 0.0001$). The autism group showed a significant negative slope ($b = -0.33$, $t(102) = -5.61$, $p < 0.0001$) (see Figure 1), indicating a decrease in abnormal low threshold auditory processing over age. The slope for the controls was not significant ($b = 0.08$, $t(102) = 1.43$, $p < 0.16$).

High threshold auditory processing showed a significant main effect for group ($F(1, 194) = 118.05$, $p < 0.0001$), with persons with autism ($\bar{X} = 2.70$, SD = 1.21) showing greater high threshold auditory dysfunction than the controls ($\bar{X} = 1.03$, SD = 1.03). There was also a main

Table 2 ***p*-values for the four sensory modalities: total, low threshold and high threshold**

Category	*Group p-value <*	*Age p-value <*	*Age × Group p-value <*	*Age regression (slope) p-value <*
Auditory				
Total	0.0001	0.006	0.004	Autism 0.0001 Control n.s.
Low threshold	0.0001	0.007	0.0001	Autism 0.0001 Control n.s.
High threshold	0.0001	0.002	n.s.	Autism 0.008 Control 0.03
Visual				
Total	0.0001	n.s.	0.04	Autism 0.0003 Control n.s.
Low threshold	0.0001	n.s.	0.005	Autism 0.004 Control 0.005
High threshold	0.0001	n.s.	n.s.	Autism 0.02 Control n.s.
Oral				
Total	0.0001	n.s.	n.s.	Autism 0.0006 Control n.s.
Low threshold	0.0001	0.0008	n.s.	Autism 0.0001 Control n.s.
High threshold	0.0001	n.s.	n.s.	Autism 0.0008 Control n.s.
Touch				
Total	0.0001	n.s.	n.s.	Autism 0.006 Control n.s.
Low threshold	0.0001	n.s.	n.s.	Autism n.s. Control n.s.
High threshold	0.0001	0.006	n.s.	Autism 0.0002 Control n.s.

effect for age ($F(6, 194) = 3.62$, $p < 0.002$). There was no group by age interaction ($F(6, 194) = 1.20$, $p < 0.32$) (see Table 2). The age regression analyses for both groups produced negative significant slopes: autism group ($b = -0.14$, $t(102) = -2.71$, $p < 0.008$) and control group ($b = -0.11$, $t(102) = -2.27$, $p < 0.03$) (see Figure 2). These negative slopes suggest that, for both groups, there is a decrease in high threshold auditory processing scores by age. Thus, the high threshold auditory processing for both groups changes with age in the same way, but there is a general level of difference between the autism group and the control group.

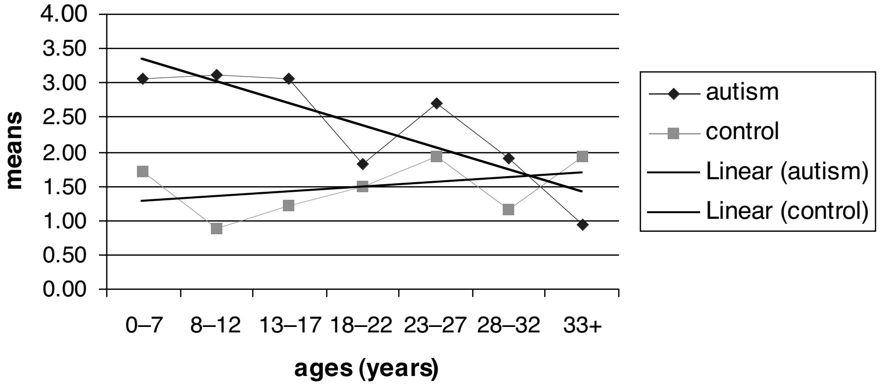

Figure 1 **Low threshold auditory processing**

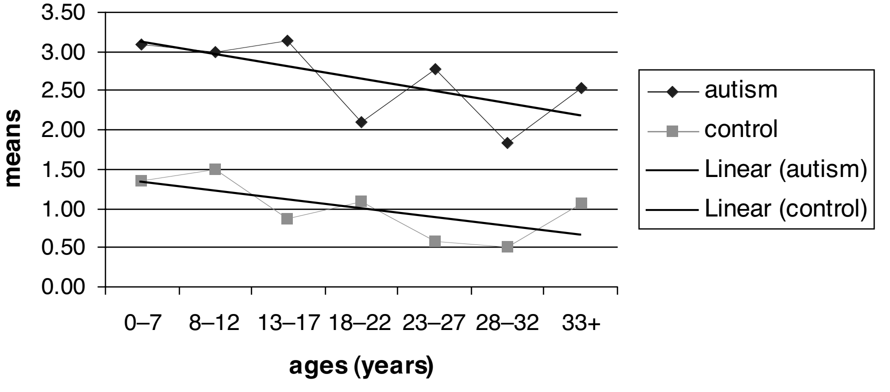

Figure 2 **High threshold auditory processing**

Visual sensory processing

For visual processing, there was a significant main effect for group ($F(1, 194) = 42.06$, $p < 0.0001$): autism ($\bar{X} = 3.96$, SD = 1.72), controls ($\bar{X} = 2.30$, SD = 1.88). There was not a main effect for age ($F(6, 194) < 1$). The main effect for group is qualified by a significant group by age effect ($F(6, 194) = 2.27$, $p < 0.04$) (see Table 2). The autism group showed a significant negative slope ($b = -0.27$, $t(102) = -3.75$, $p < 0.0003$), indicating a decrease in abnormal visual processing over age. The slope for the controls was not significant ($b = 0.14$, $t(102) = 1.57$, $p < 0.12$).

Low threshold visual processing showed a significant main effect for group ($F(1, 194) = 27.09$, $p < 0.0001$): autism ($\bar{X} = 2.42$, SD = 1.35), controls ($\bar{X} = 1.40$, SD = 1.40). There was no main effect for age ($F(6, 194) < 1$). The main effect for group was qualified by a significant group

by age effect ($F(6, 194) = 3.21$, $p < 0.005$) (see Table 2). The autism group showed a significant negative slope ($b = -0.18$, $t(102) = -3.03$, $p < 0.004$) (see Figure 3), indicating a decrease in abnormal low threshold visual processing over age. The slope for the controls was also significant ($b = 0.19$, $t(102) = 2.92$, $p < 0.005$), indicating a possible increase in sensitivity over time.

High threshold visual processing showed a significant main effect for group ($F(1, 194) = 59.06$, $p < 0.0001$), with persons with autism ($\overline{X} = 2.15$, SD = 1.33) showing greater high threshold visual dysfunction than the controls ($\overline{X} = 0.87$, SD = 1.00). There was no main effect for age ($F(6, 194) = 1.12$, $p < 0.36$). There was no significant group by age effect ($F(6, 194) < 1$) (see Table 2). The autism group showed a significant negative slope ($b = -0.14$, $t(102) = -2.39$, $p < 0.02$) (see Figure 4), indicating a

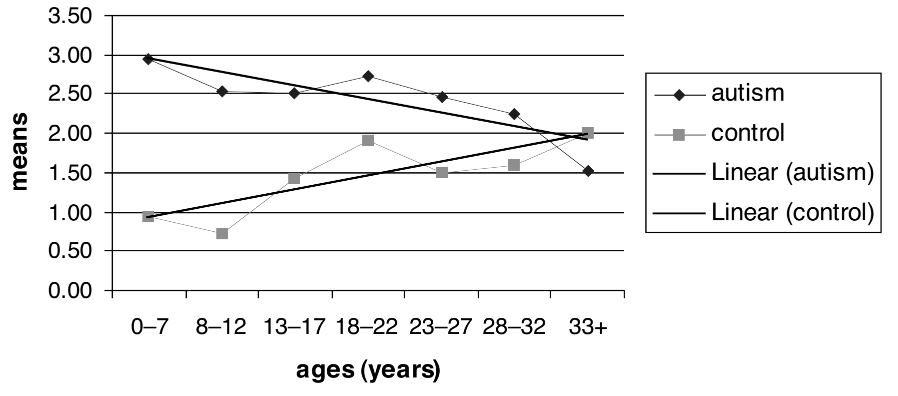

Figure 3 **Low threshold visual processing**

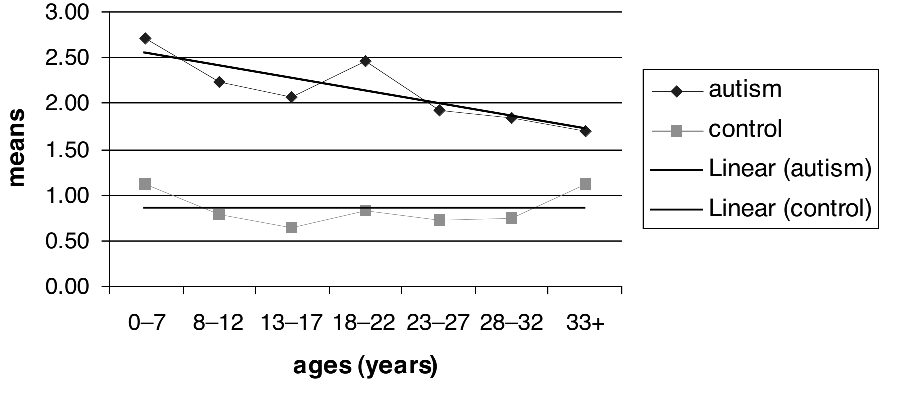

Figure 4 **High threshold visual processing**

decrease in abnormal high threshold visual processing over age. The slope for the controls was not significant ($t(102) < 1$).

Oral sensory processing

For oral processing, there was a significant main effect for group ($F(1, 194) = 52.04$, $p < 0.0001$), with persons with autism ($\bar{X} = 3.74$, SD = 2.12) showing greater oral dysfunction than the controls ($\bar{X} = 1.76$, SD = 1.69). There was no main effect for age ($F(6, 194) = 1.99$, $p < 0.07$). There was no significant group by age effect ($F(6, 194) = 1.30$, $p < 0.26$) (see Table 2). The autism group showed a significant negative slope ($b = -0.33$, $t(102) = -3.55$, $p < 0.0006$), indicating a decrease in abnormal oral processing over age. The slope for the controls was not significant ($t(102) < 1$).

Low threshold oral processing showed a significant main effect for group ($F(1, 194) = 34.08$, $p < 0.0001$), with persons with autism ($\bar{X} = 1.63$, SD = 1.29) showing greater low threshold oral dysfunction than the controls ($\bar{X} = 0.70$, SD = 0.90). There was a main effect for age ($F(6, 194) = 4.00$, $p < 0.0008$). There was no significant group by age effect ($F(6, 194) = 1.11$, $p < 0.3595$) (see Table 2). The autism group showed a significant negative slope ($b = -0.23$, $t(102) = -4.20$, $p < 0.0001$) (see Figure 5), indicating a decrease in abnormal low threshold oral processing over age. The slope for the controls was not significant ($b = -0.08$, $t(102) = -1.93$, $p < 0.06$).

High threshold oral processing showed a significant main effect for group ($F(1, 194) = 29.61$, $p < 0.0001$), with persons with autism ($\bar{X} = 2.47$, SD = 1.45) showing greater high threshold oral dysfunction than the controls ($\bar{X} = 1.37$, SD = 1.33). There was no main effect for age ($F(6, 194) = 1.25$, $p < 0.29$). There was no significant group by age effect ($F(6, 194) = 1.81$, $p < 0.10$) (see Table 2). The autism group showed a significant negative slope ($b = -0.22$, $t(102) = 3.45$, $p < 0.0008$) (see Figure 6), indicating a decrease in abnormal high threshold visual processing over age. The slope for the controls was not significant ($F(1, 102) < 1$).

Touch sensory processing

For touch processing, there was a significant main effect for group ($F(1, 194) = 197.38$, $p < 0.0001$), with persons with autism ($\bar{X} = 4.54$, SD = 1.45) showing greater touch dysfunction than the controls ($\bar{X} = 1.64$, SD = 1.51). There was no main effect for age ($F(6, 194) = 1.76$, $p < 0.1103$). There was not a significant group by age effect ($F(6, 194) = 1.15$, $p < 0.34$) (see Table 2). The autism group showed a significant negative slope ($b = -0.18$, $t(102) = -2.82$, $p < 0.006$), indicating a decrease in abnormal

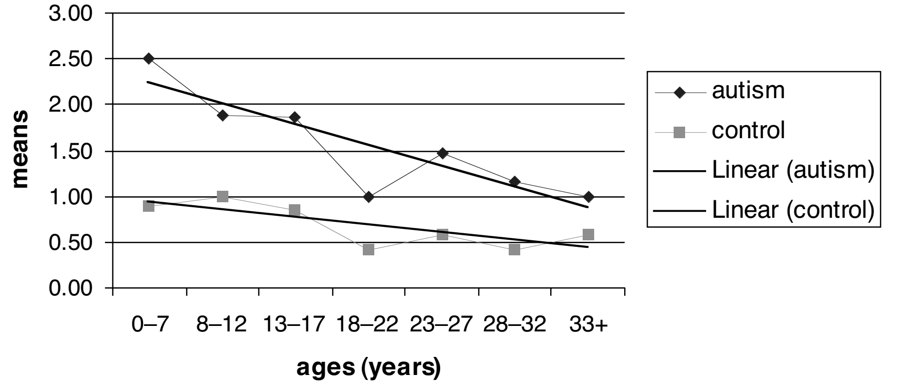

Figure 5 **Low threshold oral processing**

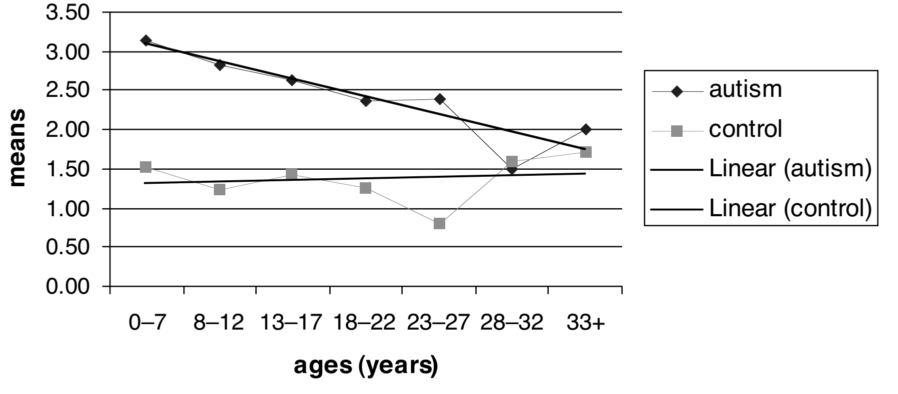

Figure 6 **High threshold oral processing**

touch processing over age. The slope for the controls was not significant ($t(102) < 1$).

Low threshold touch processing showed a significant main effect for group ($F(1, 194) = 117.48$, $p < 0.0001$), with persons with autism ($\bar{X}$ = 2.88, SD = 1.11) showing greater low threshold touch dysfunction than the community controls ($\bar{X}$ = 1.20, SD = 1.12). There was no main effect for age ($F(6, 194) = 1.87$, $p < 0.09$). There was not a significant group by age effect ($F(6, 194) = 1.31$, $p < 0.26$) (see Table 2). The slopes for both groups were non-significant: autism ($b = -0.09$, $t(102) = -1.82$, $p < 0.08$), controls ($b = 0.06$, $t(102) = 1.07$, $p < 0.29$) (see Figure 7), indicating no significant change in either group.

High threshold touch processing showed a significant main effect for group ($F(1, 194) = 140.15$, $p < 0.0001$), with persons with autism ($\bar{X}$ =

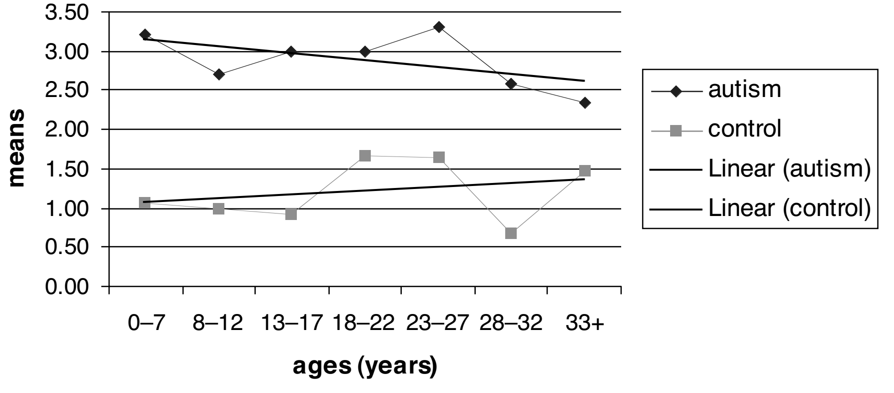

Figure 7 **Low threshold touch processing**

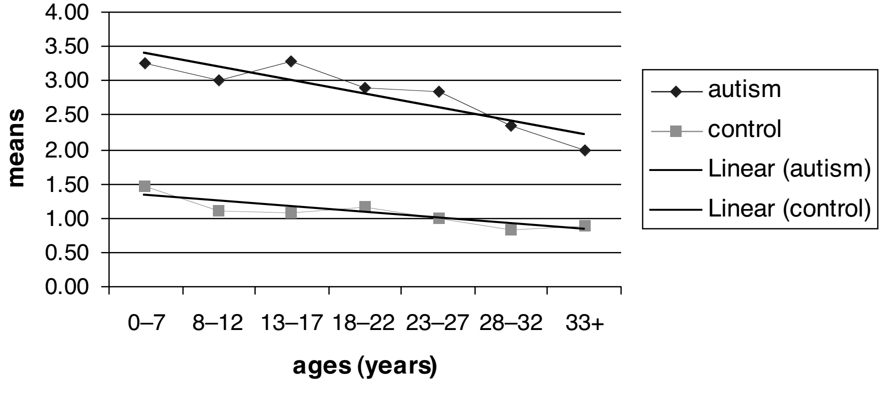

Figure 8 **High threshold touch processing**

2.82, SD = 1.15) showing greater high threshold touch dysfunction than the controls ($\bar{X}$ = 1.09, SD = 0.98). There was a main effect for age ($F(6, 194) = 3.15$, $p < 0.006$). There was no significant group by age effect ($F(6, 194) < 1$) (see Table 2). The autism group showed a significant negative slope ($b = -0.19$, $t(102) = -3.93$, $p < 0.0002$) (see Figure 8), indicating a decrease in abnormal high threshold touch processing over age. The slope for the controls was not significant ($b = -0.08$, $t(102) = -1.85$, $p < 0.07$).

Discussion

There were significant group differences on all four modalities: auditory, visual, touch, and oral sensory processing. This was so even when the high and low threshold aspects of the auditory, visual, oral, and touch processing were examined separately, indicating that the abnormal processing

involves both high and low threshold categories (sensory seeking and sensory defensiveness). In the group with autism, the abnormal auditory, visual, oral, and touch processing changed over the age groups, appearing to become more similar to the control data in time. In the group with autism, the change over time was also apparent when the high and low threshold aspects of the auditory, visual, oral, and touch processing were examined separately, except for low threshold touch (see Figures 1–8). The change over time in this category (low threshold touch) was not significant (Figure 7). There was a significant interaction in low threshold auditory and low threshold visual, suggesting that the two groups change differently over these variables; the group with autism showed a decrease in auditory and visual sensitivity, and the control group showed an increase in auditory and visual sensitivity with age.

In the control group, there was no significant change with age in auditory, visual, oral, and touch processing, when examined as a whole. However, when the high and low threshold aspects of the auditory, visual, oral, and touch processing were examined separately, the controls showed a significant change in high threshold auditory processing (a decrease with age) and low threshold visual processing (an increase with age) (Figures 2 and 3). This finding may suggest that typically developing individuals become more hearing responsive with age and may become somewhat more light sensitive with age.

This study is in agreement with parental reports. Many parents that have participated in previous studies by some of the authors of this study have reported that their child displayed more signs of sensory processing difficulties when they were younger.

It is important to try to understand sensory problems in autism because it can enable us to better understand the behavior and needs of persons with autism, and in turn, influence treatment protocols. Behavioral studies such as this one, combined with physiological studies, can eventually unravel what is happening neurologically and better specify treatments.

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